INFLUENCE OF RIPARIAN LANDFORM ON LARGE WOODY DEBRIS INPUT AND MOVEMENT IN A BLACKWATER COASTAL PLAIN STREAM

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Abstract. Large woody debris (LWD) is recognized as a major element in the structure and function of streams. In the Coastal Plain, wood may be the site of greatest invertebrate community diversity and productivity. However, little is known about factors controlling wood inputs or its long term fate. We measured wood inputs and characteristics from undisturbed riparian forest into a 5th-order stream following Tropical Storm Alberto (July 1994). Our results indicate that infrequent floods cause significant LWD inputs to Coastal Plain streams. Mortality rates and physical characteristics of LWD varied substantially across riparian landforms. Tree mortality in mature riparian forests from natural flooding benefits streams by providing critical habitat, i.e. wood debris.

INTRODUCTION

Large woody debris (LWD) is an important element in the structure and function of streams. It provides cover for fishes (Dolloff, 1986). It is often one of the few stable surfaces in sandy-bottom Coastal Plain streams, making it a site of high invertebrate activity (Benke et al., 1984). Wood debris also increases channel surface area and roughness, promoting nutrient cycling, material storage, and increasing overall stream productivity (Wallace and Benke, 1984). Finally deposits of wood within the active channel or on floodplains promote sediment retention, providing sites for forest establishment and creating habitat diversity along stream corridors (Fetherston et al., 1995).

Throughout the U.S., wood is commonly removed from stream channels to facilitate navigation, to promote drainage, or to provide wood products. Thus, the long term dynamics and ecological role of wood are poorly understood. Recent flooding during the summer of 1994 permitted us to begin a long term study of wood dynamics in a 5th-order Coastal Plain stream. In particular, we measured the influence of riparian landform and forest structure on wood inputs to the stream. We also examined the orientation and position of individual downed trees to assess differences in wood retention across differing reach types. As a portion of our long-term study program we are following the fate of downed trees within the stream.

STUDY SITE

This study was conducted in Ichawaynochaway Creek, a 5th-order black-water coastal plain stream. Our study reaches were on the Ichauway Ecological Reserve, a 10,500 ha remnant tract of longleaf pine (*Pinus palustris*) forest in Baker County of southwest Georgia.

Repeating riparian landforms and forest types occur along the stream corridor (Palik et al., 1996). Floodplain terraces (FP) occupy the lowest topographic position along the stream (< 3 m above baseflow). Their soils are well-drained fine sandy loams, with a forest canopy dominated by live oak (*Quercus virginiana*), sweet gum (*Liquidambar styraciflua*), and southern sugar maple (*Acer saccharum* subsp. *floridanum*). Low terraces (LT) and sand ridges (SR) occupy intermediate and high topographic positions along the stream corridor (2-7 m). Their soils are thick (> 2 m) and their forest canopies variable. Low terraces and sand ridges that have experienced frequent surface fires are dominated by longleaf pine (*Pinus palustris*), turkey oak (*Q. laevis*), and sand post oak (*Q. margaretta*). Where frequent surface fires have been excluded, either natually or because of human management, canopy dominants are mesic hardwoods including: laurel oak (*Q. hemisphaerica*), southern magnolia (*Magnolia grandifolia*) and pig-nut hickory (*Carya glara*).

Generally, flow in Ichawaynochaway Creek is low and stable from summer through autumn. Late winter and early spring storms often result in bankfull discharges and cause flooding of low-lying riparian areas. Average annual discharge is 22 m^3 per sec (Stokes et al., 1991). Riparian areas within the Reserve and along the entire stream have not been extensively disturbed by human land use.

Tropical Storm Alberto

During July 3-7, 1994, parts of southwest Georgia, including the upper portions of the Ichawaynochaway

Creek Drainage received up to 28 inches of rain from Tropical Storm Alberto (Hippe et al., 1994). During the storm, peak daily discharge on Ichawaynochaway Creek was estimated at 850 m^3 per sec and instantaneous peak discharge was estimated at 1400 m^3 per second (Hippe et al., 1994). Extensive flooding occurred and extended well into the uplands throughout the drainage. A subsequent series of tropical storms and depressions resulted in above average discharge throughout the summer and autumn of 1994.

Method of Analysis

Field Measurements. Tropical Storm Alberto resulted in substantial tree mortality along Ichawaynochaway Creek. Characteristics of forest structure and downed trees were recorded during the autumn of 1994. Measurements were made on forest segments along the east and west banks of 6 riparian study areas. Forest segments and downed trees on east and west banks were treated independently during data analysis because riparian landforms were not always similar between banks. This allowed us to examine the effect of reach shape (inside meander, outside meander, or straight) on downed tree characteristics.

Sampling focused on the forests growing on the natural levees along the active stream channel. Levees were the site of highest tree mortality and the most likely source of wood debris to the stream. Levees are approximately 5 m wide.

Woody vegetation of stream-side forests was sampled using the point-quarter method (following Brower and Zar 1984). In each reach, an initial starting point was located by pacing a random distance in a direction parallel to the stream, beginning at one end of the sample area. Additional points were located at 40 m intervals. In each quarter of a point, the nearest woody stems in two size classes (diam. 5 - 10 cm at 1.4 m; diam χ 10 cm) were identified, diameter and distance to the point were noted. Data were summarized to determine reach composition and densities per stream length.

Measurements on downed trees included counts of tree mortality, distance from baseflow channel, contact with baseflow channel, orientation with respect to current flow, and tree condition (presence of intact rootwad, presence of branches). Characteristics of downed trees were expressed as rates (# per km shoreline), or frequencies (% of total downed trees). Lengths of forest segments were determined using a GIS data layer.

Geomorphic position for each riparian forest was assigned using an ecological classification (Palik et al. 1996). Reach shape was determined from field observations and examination of aerial photographs.

Data Analysis. Redundancy Analysis (RDA) was used to explore the relationships between characteristics of downed trees and physical characteristics of riparian segments. RDA is a form of constrained linear ordination, or direct gradient analysis, that is similar to Canonical Correspondence analysis (CCA), but has the advantage of not requiring sample sizes which greatly exceed the combined number of dependent and independent variables (Ter Braak and Prentice 1988). Dependent variables (i.e. characteristics of downed trees) used in the ordination are listed in Table 1. Independent variables (i.e. physical characteristics of riparian areas) included landform ranking (FP -- low topographic position, low channel constraint; LT --intermediate topographic position and constraint; SR -- high topographic position and constraint), meander shape (inside curve, outside curve, straight), and reach length. The ordination was exploratory in nature; designed to formulate hypotheses rather than test them. RDA was performed on correlation matrices of untransformed data.

RESULTS

Pooled over all sites, tree mortality averaged 22 downed trees per km of streambank (Table 1). This represented about 10% of the canopy dominants. A majority of downed trees were in contact with the baseflow channel. Most downed trees were intact (minimal damage to branches), had intact roodwads, and were still anchored to the stream bank (Table 1). Although several bankfull or near bankfull discharges have occurred since July 1994, little movement or rearrangement of downed trees has occurred. Most remain in their original position and orientation.

Table 1. Summary Satistics for Characteristics of Downed Trees Used in Redundancy Analysis (n=12 forest segments)

	Mean	S.D.	range
Ave. distance from baseflow(m)	0.9	1.1	0.0-0.3
Mortality (# per km stream)	22.3	31.5	2.1-103.9
Mortality (%)	9.9	15.7	0.9-53.1
Contact with channel (%)	66.6	30.7	11.6-100.0
Perpendicular to channel (%)	42.4	40.3	0.0-100.0
Parallel to channel (%)	56.6	42.1	0.0-100.0
Rootwad present (%)	85.7	13.4	66.7-100.0
Snag Intact (%)	76.3	19.1	50.0-100.0

Redundancy analysis between the characteristics of downed trees and physical characteristics of riparian segments accounted for 31.8% of the total variation among segments with respect to downed tree characteristics. Most of the variation (26%) was accounted for by the first RDA axis (Figure 1). Correlation coefficients between characteristics of downed trees and riparian segments were 0.664 and 0.786 for the first and second RDA axes, respectively. Several relationships between characteristics of downed trees and riparian segments were suggested by the analysis. On RDA axis 1, greater mortality rates were associated with landforms having constrained stream valley walls (i.e. low terraces and sand ridges), and straight reaches. Downed trees in those segments tended to be oriented parallel to stream flow, and the average distance from downed trees to the baseflow channel tended to be greater than other segments. In contrast, curved segments and those with unconstrained reaches had lower mortality, with downed trees oriented perpendicular to flow and in contact with the baseflow channel. On RDA axis 2, segment length was correlated with intactness of downed trees, i.e. longer segments had a greater frequency of intact downed trees.

Natural levees along our riparian study areas support a diverse plant community. More than 50 woody species have been identified (Palik, unpublished data). Tree species varied greatly in their susceptibility to mortality from flooding. For river birch (*Betula nigra*) and red cedar (*Juniperus virginia*) percent mortality was significantly greater than percent abundance, indicating high susceptibility to flood damage (Figure 2). For oaks (*Quercus spp*), there was no significant difference

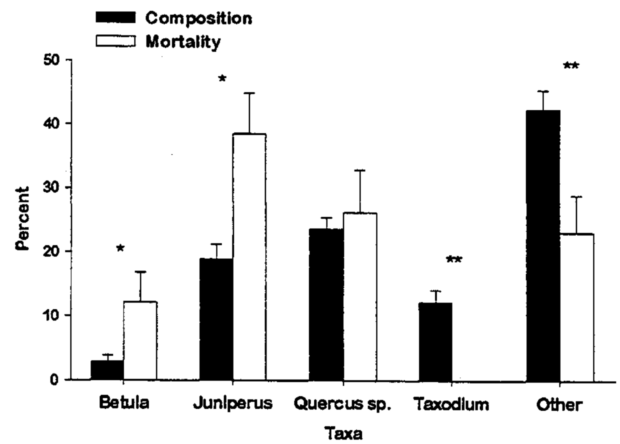

Figure 1. Comparison of composition and mortality by taxa for downed trees. Astericks indicate significant differences between relative abundance and mortality (* p<0.05, ** p<0.01).

between relative abundance and percent mortality. Cypress (*Taxodium distichum*) was very resistant to flooding, no downed cypress were found in our riparian study areas even though cypress represented about 12 % of the forest population. Other taxa (pooled) also appeared to be resistant to flooding.

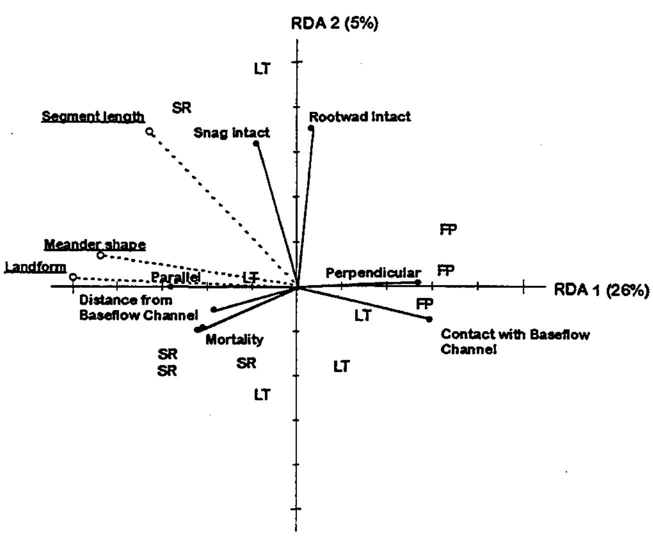

Figure 2. Ordination based on RDA analysis of forest segment and downed tree characteristics.

DISCUSSION

Downed trees are very stable in Ichawaynochaway Creek. Little movement of snags has occurred even though they have been exposed to subsequent floods. We attribute stability to stream morphology; the low gradient and forested floodplain reduces the force of flood waters. Stability is also linked to characteristics of downed trees. Most snags are anchored at multiple points (both branches and intact rootwads). Attachment to banks minimizes movement during floods. Long term studies will reveal whether movement occurs following breakdown of branches and rootwads or whether most downed trees decompose in place.

Landform interacts with hydrology to determine wood inputs. Geologically constrained areas (low terraces and sand ridges) had higher tree mortality. We attribute greater mortality to greater current velocities during floods. Also, different mechanisms of mortality appear to operate across landforms. In floodplain terraces, trees appear to be undermined and collapse into the stream. In sand ridges, trees appear to be uprooted by the current and deposited on the bank. Although mortality was lower in floodplain terraces, more trees were deposited into stream.

Thus, wood inputs from floodplain terraces may have a greater influence on instream processes than sandridges.

Trees vary greatly in their susceptibility to floods. Eastern Red Cedar and River Birch were very prone to flood damage. Both trees have many small branches and dense foliage, this growth form may expose them to greater current force during floods. Cypress was very resistant to flood damage even though many grow near or within the baseflow channel. Cypress have few low branches. Sparse foliage in combination with an extensive buttressing root system appear to make cypress very resistant to floods.

SIGNIFICANCE TO WATER RESOURCES

Since European settlement of North America, humans have altered most streams and rivers (Stanford et al., 1996). Human disturbance has included extensive pollution (point and non-point), and hydrologic alteration (river regulation and channelization). To date, research and conservation efforts have focused on pollution (Naiman et al., 1995). While clean water is important, there is a growing recognition that natural hydrologic regimes, or managed hydrologic regimes that simulate natural cycles of flooding, are essential to in maintaining stream health (Stanford et al., 1996). Our study supports the idea that natural floods contribute to stream biotic integrity. In this case, large floods result in substantial inputs of wood debris, a critical habitat in Coastal Plain streams.

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